Art, Craft and Philosophy of Science

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- *"Blessed is the man who having nothing to say abstains from giving wordy evidence to that fact."*

George Eliot

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- Is the capacity for language inherent in us?

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- Is the truth to an object mere convention of language?

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$\Rightarrow$ These and many other related questions have troubled philosophers from times immemorial.

- There is a tremendous need for precision of Language. As Ruskin aptly remarks:
  ". . . and, therefore, first of all, I tell you, earnestly and authoritatively, (I know I am right in this,) you must get into the habit of looking intensely at words, and assuring yourself of their meaning, syllable by syllable-nay, letter by letter. For, though it is only by reason of the apposition of letters in the function of signs, to sounds in function of signs, that the study of books is called 'literature', and that a man versed in it is called, by the consent of nations, a man of letters, instead of a man of books, or of words, you may yet connect with that accidental nomenclature this real principle-that you might read all the books in the British Museum (if you could live long enough); and remain an utterly 'illiterate', uneducated person;

- *" but that if you read ten pages of a good book, letter by letter,- that is to say, with real accuracy, - you are for evermore in some measure an educated person. The entire difference between education and non-education (as regards the merely intellectual part of it), consists in this accuracy. A well-educated gentleman may not know many languages, may not be able to speak any but his own, may have read very few books. But whatever language he knows, he knows precisely; whatever word he pronounces, he pronounces rightly; above all, he is learned in the peerage of words, knows the words of true descent and ancient blood, at a glance, from words of modern canaille;*

- *"remembers all their ancestry-their inter-marriages, distantest relationships, and the extent to which they were admitted, and offices they held, among the national noblesse of words at any time, and in any country. But an uneducated person may know by memory any number of languages, and talk them all, and yet truly know not a word of any, -not a word even of his own."*

Opposite Point of View

- *"The sentence is considered as an indivisible and integral linguistic symbol. And the meaning conveyed by it is an instantaneous flash of insight or intuition. The meaning is also partless. The words have no reality of their own; they are only hints that help the listener to arrive at the meaning. Many of the problems in the study of meaning in linguistics are based on the primary assumption that words are the counters of thought; but when once that assumption is set aside and words given their proper place in the language system as unreal abstractions just like roots and suffixes, many of these problems fade away. The words have a reality only at the pragmatic level. This theory of Bhartrhari may be a welcome corrective to the prevailing tendency among some modern linguists to lay undue stress on words."*

Kunjunni Raja

- *"The history of linguistics does not begin in Greece but in India. The proper way to introduce the subject would therefore be to start there and mention the West only when Indian ideas were introduced into European speculations about language. This would conflict with prejudices of long standing, e.g., that science is an exclusively Western development, and be misleading because it would not explain why Indians ideas were so long and consistently misunderstood in the West."*

Staal

- *"Ancient Indian grammarians were centuries ahead of their European counterparts in language studies and from their best known scholar, Panini, whose studies still extant, date back to the second half of the first millennium BC, we see brilliant independent linguistic scholarship in both theory and practice. Phonetic description in this and other, later Indian works were not matched in the west until at least the seventeenth century. Nor were they equaled in grammatical analysis which involved ordered rules of word formation and extreme economy of statement."*

  Encyclopedia of Linguistics (1996)

- *"The Sanskrit language, whatever be its antiquity, is of a wonderful structure; more perfect than the Greek, more copious than Latin, and more exquisitely refined than either, yet bearing to both of them a strong affinity, both in the roots of words and in the form of grammar, than could possibly have been produced by accident; so strong indeed, that no philologer could examine all three, without believing them to have sprung from some common source, which, perhaps, no longer exists: there is reason, though not quite so forcible, for supposing that both the Gothic and the Celtic, though blended with a very different idiom, have the same origin with Sanskrit; and Old Persian might be added to the same family."*

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- *"...a more scientific and empiricist approach was introduced into Western linguistics only after the discovery of Sanskrit ."*

  Sarton

- *"We are tempted to think that action of language consists of two parts; an inorganic part, the handling of signs, and an organic part, which we may call understanding these signs, meaning them, interpreting them, thinking. These latter activities seem to take place in a queer kind of medium, the mind; and the mechanism of the mind, the nature of which, it seems, we don't quite understand, can bring about effects which no material mechanism could."*

Wittgenstein

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- Explanations are the answers to the question “why?”
- The diverse ways in which we use the word “why”, and thus the ambiguity in its meaning, is discussed at length by Nagel (1984). He discusses ten different ways in which we use the word “why?” (Ten different meanings to it) and these ten by no means exhaust the ways in which the word is used. I shall not repeat all of them in detail but just mention some of the different ways.

- The answer to “why?” can be a demonstration which establishes not only universal truth but also the necessity of the “*explicandum*”, as in the case why is the sum of any number of consecutive odd integers beginning with unity “always a perfect square”.

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- In the case of the explanation to why did moisture form on the outside of the glass when it was filled with ice water yesterday, the explicandum is not a necessary truth. Sometimes the explicandum is described statistically and is not an individual event. Sometimes the explicandum is a historical fact and at other times it is a universal law, and at other times the question “why?” elicits explanations in terms of psychological dispositions, while at other instances the answers are teleological explanations.

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flammable	inflammable
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- Same word can mean exactly the opposite based on the context

“He ran fast”	Signifies Movement
“He stood fast”	Signifies Lack of Movement

- *"We think only through the medium of words. - Languages are true analytical methods.- Algebra, which is adapted to its purpose in every species of expression, in the most simple, most exact, and best manner possible, is at the same time a language and an analytical method.-The art of reasoning is nothing more than a language well arranged."*

Abbe de Condillac

- The “truth” of a statement can change with time. The statement “The human population of the United States of America is less than 200 million” while true in the past is clearly untrue today. Likewise, the truth of a statement can depend on social considerations. The statement “bigamy is illegal” while true in the United States is clearly untrue is some Islamic countries. Thus, one has to be careful about evaluating the truth of a statement.

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- We might have to take into account temporal, geographical, social and other considerations. While the statement that the “Sun rises everyday” can be considered a scientific fact today, if we are to believe our astrophysicists, it will cease to be true when it eventually explodes. This of course does not necessarily render true the statement “humankind will perish when the sun explodes”, for by that time human kind might have figured a way to move out of the Solar System!

- If the meaning of a sentence is not clear, then we can never assess whether the sentence is true or false. In philosophy, there is a great deal of disputations concerning whether sentences have meaning or whether it is propositions as abstract entities which are expressed by these sentences that have meaning but not the sentences themselves.

- *"Philosophy informs us, that everything which appears to the mind, is nothing but a perception, and is interpreted, and dependent on the mind; whereas the vulgar confound perceptions and objects, and attribute a distinct continued existence to the very things they feel or see."*

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- *"Thought cannot turn toward the world of external objects without at the same time reverting to itself; in the same act it attempts to ascertain the truth of nature and its own truth."*

  Ernst Cassirer

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- The sensory inputs are processed by our mind and thus Psychology attempts to provide a scientific basis for our mental states, the mental processes, how we think, feel, interpret and express ourselves.
- Though Psychology today stands for much more than enquiry into the mind, it is to this aspect of Psychology, as it impacts on science, we will address a few comments.

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- Regarded as an enquiry into how the mind functions, Psychology becomes a part of Philosophy. It is of relevance to science, since science depends on the collection of facts, and one of the primary means for acquiring facts is sensory perception, and it is the mind that interprets these perceptions.
- There is a popular misconception that the sciences, especially the natural sciences are objective subjects and are independent of an individual's nature or for that matter, or human nature.

- *"It is evident, that all the sciences have a relation, greater or less, to human nature; and that, however wide any of them may seem to run away from it, they still return back by one passage or another. Even Mathematics, Natural Philosophy and Natural Religion are in some measure dependent on the science of MAN; since they lie under the cognisance of men, and are judged by their powers and faculties. If, the sciences of Mathematics, Natural Philosophy, and Natural Religion, have such a dependence on the knowledge of man, what may be expected in the other sciences, whose connection with human nature is more close and intimate."*

Hume

- *"The only laws of matter are those which our minds must fabricate, and the only laws of mind are fabricated for it by matter."*

  Maxwell

- All Our sensory organs are constantly receiving signals from the external world, some of which they register subconsciously, others that they register consciously and interpret the information, and yet others that it sees and chooses to ignore (sees but does not observe). These impression are fed into our mind which then interprets them. It is necessary to recognize the philosophical issues concerning the interaction of a person with the world of external objects.

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- Our knowledge of the world, whether it is scientific or sociological, stems from our experiences in the world and from our point of view. Our point of view is from our birth, shaped by our environment, but we cannot completely ignore the individuality of the perceiver.

- *"By education most have been misled;*
  So they believe, because so they were bred,
  The priest continues what the nurse began,
  And thus the child imposes on the man."

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- People think they are thinking when they are merely rearranging their prejudices.

  William James

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- *"One does not need to know how the digestive process works in order to enjoy a good meal."*

  Heaviside

- *"There is nothing more necessary to the man of science than its history, and the logic of discovery: the way error is detected, the use of imagination, the mode of testing."*

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- *" One of the main reasons for studying and teaching the history of science is to give educated men in general, and to professional scientists in particular, a better sense of proportion."*

  Sarton

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- *"The spirit of Greek science, which accomplished such wonders within a period of about five centuries, was essentially the western spirit, whose triumphs are the boast of modern scientists. But we must bear in mind two important qualifications. First, that the foundations of Greek science were wholly oriental, and however deep the Greek genius it is not certain that it would have built anything comparable to its actual achievements without these foundations. When discussing the fate of a man of genius, we may make many suppositions, but it would be absurd to wonder what would have happened if he had other parents, for then he would never have been. In the same way we have no right to disregard the Egyptian father and the Mesopotamian mother of the Greek genius."*

Sarton

- *"A history of the Greek experimental science, outside of medicine would be exceeding by short. Under the influence of Arabic alchemists and opticians and later of Christian mechanicians and physicists the experimental spirit grew very slowly."*

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- *"Everything of importance has been said before by somebody who did not discover it."*

A. N. Whitehead

- *"The genius of Newton lay in the patient thoroughness with which he worked out details of what he called on the title-page of his immortal work, the 'Mathematical Principles of Natural Philosophy' (1687; ed.2, 1713, ed. 3, 1726). But the main idea of that work is nothing more or less than Descartes idea of a universal science mathematical in its form; the rules of method which he lay down at the beginning of his third book are drawn from Bacon; and the cosmology that he develops is nothing but Galileo's cosmology, according, to which the natural world is a world of bodies possessing extension, figure, number, motion and rest, modified by Kepler's idea of force and Gilbert's hypothesis of universal attraction between body and body: this natural world being regarded in the fashion of Galileo as a machine made by God and known by human beings who, in the capacity of sentient creatures, ingest it with secondary qualities of colour, sound, and so forth, which in its own right it does not posses."*

Collingwood

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- *"We should construct a whole new mechanics —-where, inertia increasing with velocity, the velocity of light would be an impassable limit.*

Atomic Theory

- *" Treatises on early Greek philosophy customarily regard Empedocles as the originator of the theory of elements. There are, however, references in the earliest of Upanishads, long before the time of Empedocles, e.g., B. A. Upanishad. III , Chapter VII, 7-1."*

G. Whiteman

- *" I am now convinced that theoretical physics is actually philosophy."*

Max Born

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- *" This is the end I aim at: to acquire knowledge of the union of mind with the whole of nature. To do this it is necessary first to understand as much of nature as success for acquiring such knowledge, and to form a society of the kind which permits as many as possible to acquire such knowledge."*

Spinoza

- To the early Greeks, physics had a far wider scope than what it connotes today. The Oxford English Dictionary defines physics as " *Natural Science in general, especially the Aristotelian system of Natural Science, hence Natural Philosophy in the wider sense.*" It goes on to add that *"The application of the term has continually tended to be narrowed. It originally (from Aristotle) included the study of the whole of nature (organic and inorganic): Locke even included spirits (gods, angels, etc.) into its objects. In the course of the 18th century it became limited to inorganic nature, then by excluding chemistry, it acquired its present meaning."*

- *"Natural Science does not simply describe and explain nature; it is the part of the interplay between nature and ourselves; it describes nature as exposed to our method of questioning."*

  Heisenberg

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- By drawing a divide between the rest of nature and ourselves, Heisenberg is hiding one of the most interesting aspect of natural science and one of its chief problems which he understood better than most, namely its evaluation, characterization, and attempted description from within, namely by ourselves. To think of ourselves as being outside of nature impoverishes both ourselves and nature. Human beings are an integral part of nature and are devoid of meaning otherwise.

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- Metaphysics does not mean that which is beyond physics. While it came to be misinterpreted as the "*state of things transcending what is physical or natural" and hence synonymous with the "super natural".*
- It only means "*That branch of speculative inquiry that treats of first principles of things including such concepts as being, substance, essence, time, space, cause, identity, etc., theoretical philosophy as the ultimate science of being and knowing".*

- The word meta when used as a prefix here; does not, or rather should not, signify that which is above or beyond the word following the prefix. However it has commonly been misused as such and has thus created a great deal of confusion. The more general definition of physics as natural science is a part of metaphysics viewed within the general definition given above, while metaphysics includes other branches of speculative enquiry. Thus, to think of physics as distinct from metaphysics is clearly incorrect when the word metaphysics is used in the above sense.

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- The recent use of the term metaphysics assigns to it all areas in the general definition given above sans natural science, that is by metaphysics nowadays we usually mean Cosmology, Ontology, Epistemology and Eschatology.

- *"Science and Philosophy aim ultimately at the same ends. Science starts from a detailed examination of particulars and Philosophy start from the general and tries to explain the particular. It may be said that science does not touch the really fundamental things; its method is the modest one of starting with the humble, even the apparently trivial . . . It builds a broad Pyramid resting upon observed facts... The general conclusions are rather to be thought of as the apex of a broad based pyramid than the foundation on which the building rests."*

George Thomson

- Thus in truth, there is a wonderful interplay between physics and metaphysics. The meaningful metaphysics of yesteryears transform themselves into the physics of today and the sensible physics of today become the seeds for the metaphysics of the morrow.

- Thus in truth, there is a wonderful interplay between physics and metaphysics. The meaningful metaphysics of yesteryears transform themselves into the physics of today and the sensible physics of today become the seeds for the metaphysics of the morrow.
- *"...classical philosophers had a close connection with the science of their times, some of them, such as Descartes and Leibniz, were leading mathematicians and physicists themselves. More recently, philosophy and science have become estranged, a situation that has led to an unproductive tension between the two groups. The philosophers, whose training has usually has been acquired in the pursuit of historical and philological studies, accuse the scientist of too much specialization and turn instead into metaphysical problems; the scientists, on the other hand miss in philosophy the treatment of epistemological problems, which, though solved by Leibniz and Kant within the framework of the science of their times, demand a fresh analysis within the framework of contemporary science ."*

Hans Reichenbach

- *" The knowledge that metaphysics gives us of things is more intimate and deeper than the one provided by physics. It therefore surpasses the latter in excellence. But if metaphysics precedes physics in the order of excellence, it comes after physics in the order of logic."*

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- Many try to differentiate between physics and philosophy on the basis that physics deals with measurable quantities, its statement can be made quantitative while philosophy is primarily concerned with qualitative ideas and notions. This is somewhat an arbitrary distinction as the measurability of certain quantities is not direct but due to inference and this measurability is rendered possible by means of standardization, the standard itself being "measured" in an arbitrary manner, i.e., it is fixed as an unit. Also, there are serious difficulties with regard to measurability and commensuration and we shall not get into these issues here.

- *"Therefore metaphysics, which many say can be properly avoided in the field of physics, is in fact its only support and what gives light."*

Kant

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- When the word is used in the wider sense, the abstract science is distinguished as pure mathematics, and its concrete applications (e.g. in astronomy, various branches of physics, the theory of probabilities) as applied or mixed mathematics.

- *" Mathematics is a language."*

J. W. Gibbs

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- One can think of what goes by the name "logic" as the grammar of mathematics and what is viewed as the "application of mathematics" to natural phenomena is akin to the use of language to describe objects and communicate.

- *"Mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true."*

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- *" Pure mathematics consists essentially of assertions to the effect that, if such and such a proposition is true of anything, that such and such a proposition is true of that thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is of which it is supposed to be true.."*

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- *"Mathematics is a game played according to certain simple rules with meaningless marks on paper."*

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- *"Mathematics is the art of giving the same name to different things."*

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- Ring, Group, Vector, Algebra

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- However, delving purely into western source is insufficient.

- *"The first is that the seeds of science, including the experimental method and mathematics in fact the seeds of all the forms of science came from the East and that during the middle ages they were largely developed by the Eastern people."*

  Sarton

- The view that Mathematics is a Discovery

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- *"I believe that the numbers and functions of analysis are not the arbitrary product of our spirits; I believe that they exist outside of us with the same character of necessity as the objects of objective reality; and we find or discover them and study them as do physicists, chemists and zoologist ."*

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  Charles Hermite
- *"I will state my position dogmatically in order to avoid minor misapprehensions. I believe mathematical reality lies outside of us, our function is to discover or observe it, and that the theorems which we prove and which we describe grand eloquently as our creations are simply our notes or observations."*

  Hardy

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- *"The question of the ultimate foundations and ultimate meaning of mathematics remains open; we do not know in what direction it will find its final solution or even whether a final objective answer can be expected at all. "Mathematizing" may well be a creative activity of man, like language or music, of primarily originality, whose historical decisions defy complete objective rationalization."*

Weyl

- *"The very possibility of mathematical science seems an insoluble contradiction. If this science is only deductive in appearance, from whence is derived that perfect rigour which is challenged by none? If, on the contrary, all the proposition it enunciates may be derived in order by the rules of formal logic, how is it that mathematics is not reduced to a gigantic tautology. ."*

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- **If mathematics is an objective reality "it" has to have truth to it. Its foundations cannot have the sort of uncertainties as evidenced by the results of Godel, Church, Skolem, Cohen, Lowenheim, and others.**

- *"I wanted certainty in the kind of way in which people want religious faith. I thought certainty is more likely to be found in mathematics than elsewhere. But I discovered that many mathematical demonstrations which my teachers expected me to accept, were full of fallacies, and that, if certainty were indeed discoverable in mathematics, it would be in a new field of mathematics, with more solid foundations than those that had hitherto been thought secure. But as the work proceeded, I was constantly reminded of the fable about the elephant and the tortoise. Having constructed an elephant upon which the mathematical world could rest, I found the elephant tottering, and proceeded to construct a tortoise to keep the elephant from falling. But the tortoise was no more secure than the elephant, and after twenty years of arduous toil, I came to the conclusion that there was nothing that I could do in the way of making mathematical knowledge indubitable."*

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- Quine’s Paradox: Nothing of a given kind can bear a relation to all and only the things of that kind that do not bear it to themselves.
- If by “kind” one means “class” and by “relation” one means relation of a class to its member, the above leads to Russell’s Paradox.

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- Conversely, if one has a system of axioms for the characterization of a non-denumerable set, one can find a denumerable collection that is described by it, quite differently than in the previous interpretation.

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- A complete deductive system is impossible for even so modest a fragment of mathematics as elementary number theory.

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- Are (1) and (2) Equivalent?
- The long belief in the universal validity of the principle of the excluded third in mathematics is considered by intuitionism as a phenomenon of history of civilization of the same kind as the oldtime belief in the rationality of π.

L.E.J. Brouer

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- EXPERIMENTS are then designed to corroborate the HYPOTHESES. Based on the level of corroboration one refines the Hypotheses and tests it against further experiments and this process is iterated upon several times before one comes up with a reasonable framework that can be dignified with the term THEORY. There are several demands one makes of a theory or a model and we shall consider them in what follows.

- OBSERVATIONS are the perceptions of spontaneous events by means of which Nature manifests herself, the observer has no control with regard to the events that are taking place. Observations are at two levels, a rudimentary level in which the observer does not seek anything specific to observe, such observations being forced on him by Nature such as being exposed to a tornado, a meteor shower or an eclipse for the first time.

- OBSERVATIONS are the results of our sensory perception and as we remarked before the sensory organs are subconsciously and consciously cognizing all the time. At a different level observations involve the observer choosing to observe something specific, but such an observation invariably already involves a hypothesis concerning the observable.

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- Theories stand betwixt observations and experiments; the former are perceptions of occurrences that constitute the corpus of our experience while the latter are accomplishments in which events are specifically fashioned by man, on basis of a theory (idea) with a view towards gleaning and discovering facts with which to test the theory.

- EXPERIMENT (OED): The action of trying anything, or putting it to proof; a test, trial. In science, it has a more specific meaning: An action or operation undertaken in order to discover something unknown, to test a hypothesis, or establish or illustrate some known truth.

- *"Purely experimental physics confines its activities to the exhibition of natural phenomena and a careful description of what occurs. One might, for example observe the luminous effects produced by the passage of electric current through a rarefied gas, record what is observed, and stop at that point; but today a procedure of this kind is justly regarded as being unsatisfactory. As soon as we enquire into the reasons for the phenomena, we enter the domain of theory, which on the basis of hypothesis admitting more or less direct tests, connects the observed phenomena and traces them back to a single "pure" phenomena, thus bringing about a logical arrangement of an enormous amount of observational material."*

Joos

- In deciding to perform an experiment, the experimentalist has already theorized that such an eventuality is possible, and such a theorization is usually on the basis of some observation. There is some idea that prompts the experimentalist to pass electric current through a rarefied gas. To plan an experiment to test an unobserved phenomenon requires even more reliance on a theory. Thus, pure experiment is merely pure observation of events with no specific intent to observe, sans interpretation or explanation.

- In fact, the connections between observation, experiment and theory are far more complex than the above remark of Joos. In deciding to perform an experiment, the experimentalist has already theorized that such an eventuality is possible, and such a theorization is usually on the basis of some observation.

- To plan an experiment to test an unobserved phenomenon requires even more reliance on a theory. Thus, pure experiment is merely pure observation of events with no specific intent to observe, sans interpretation or explanation. That observation at the second level cannot be made without an Hypothesis in place was not fully recognized in the early development of the philosophy of science:

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- *"About 30 years ago there was much talk that geologists ought to observe and not to theorize; and I well remember someone saying at this rate a man might as well go into a gravel pit and count the pebbles and describe the colors. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service."*

Charles Darwin

- AN ABSURD POSITION

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- *"This was the method I adopted: I first assumed some principle, which I judged to be the strongest, and then I affirmed as true whatever seemed to agree with this, whether relating to the cause or anything else; and that which disagreed I regarded as untrue."*

Plato

- An argument could be made that concepts and hypothesis are our creation and that there is no logical means for deriving them from our observations. They (observations) can at best instigate our mind to conceive such hypothesis but that there is no direct link between the observations and the hypothesis and concepts that we create. This is indeed true for different individuals confronted by the same event may perceive it differently and thus create different hypothesis.

- “For theory construction, experimentation has a two fold significance: testing for empirical adequacy of the theory as developed so far, and filling in the blanks, that is, guiding the continuation of the construction, or the completion, of the theory. Likewise, theory has a two fold role in experimentation: formulation of the questions to be answered in a systematic and compendious fashion, and as a guiding factor in the design of the experiments to answer those questions. In all this we can cogently maintain that the aim is to obtain the empirical information conveyed by the assertion that a theory is or is not empirically adequate”.

- Our ability to apprehend and cognize experiments are limited by our tools, natural and artificial, of perception. These tools inhibit and obscure our ability to get at the truth; to generalize our experience to the case of events that take too short or too long, or to objects that are too small or too large would be unwise. For instance, we cannot extrapolate to rules that are valid for bodies moving close to the speed of light from rules that seem to hold for bodies that move at the normal speeds that we are used to. The ubiquitous crutch that we turn to unfailingly appealing to anology, can oftentimes lead us astray. We tend to seek similarities in galactic as well as atomic systems. Systems which are too large or too small for us to comprehend, we tend to extrapolate from that which we can observe or that which we are used to and comfortable with.

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- A similar sentiment concerning the role of experiments is also espoused by Newton: "The way therefore to examine it, is, by considering whether experiments, which I propound, do prove those parts of the theory to which they are applied;————"
- There may be more than one hypothesis to explain a phenomenon or a set of phenomena. If there are only a finite number of hypothesis that could be possible candidates for explaining the set of phenomena in question, and if all but one of them can be proven to be false, then that one which remains, but which cannot be proven false, might be considered the true explanation. The problem here lies with the assumption that there are only a finite number of hypotheses for explaining the phenomena.

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- A theory does not merely explain observed phenomena, it has to have predictive capability, but these two characteristics are insufficient for a hypothesis to become elevated to a the status of a theory.

- A theory is not just a basis or grounds for a single observation or for that matter a set of observations, it invariably has a predictive capability in explicating events heretofore unseen and sires experiments that can test them. It is conjectural and speculative, never to be confirmed, but always liable to be disproved.Whewell (1989) requires a theory to lead to a Consilience of Inductions.

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- Whewell also believed a test for a good theory was its simplicity, but by simplicity he did not mean that it was not complicated (the usual sense of the term) but used it in an "extensionalistic sense": "One concept is simpler than another if it colligates more facts, if it has a larger detonation". Thus,the simplest theory would be a single theory that can explain all the facts concerning nature.

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- Poincare makes a similar point in the following remark. "It is because simplicity and vastness are both beautiful that we seek by preference simple facts and vast facts".

- *"Science itself therefore may be regarded as a minimal problem, consisting of the completest possible presentment of facts with the least expenditure of thought".*

Mach

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- *"Economy of communication and apprehension is the very essence of science. Herein lies its pacificatory, its enlightening, its refining elements".*

  Mach

- A theory rests on numerous hypotheses. While discussing the attributes of a hypothesis, Quine and Ullian emphasize refutability as a key virtue. While at first glance it hardly seems a desirable attribute, on careful reflection, we cannot fail to see merit to their argument. We should be able to imagine a situation in which the hypothesis could possibly fail, otherwise such a hypothesis is no more a hypothesis, it is a uncontestable fact or a untestable hypothesis. Testability implies refutability and vice versa and Popper argues that the scientific method consists in the development of testable hypothesis which we try to falsify, rather than trying to confirm them in specific instances by generating corroborative evidence, as such evidence in no way can really confirm them in toto.

- *"It is a rather zigzag pattern that the curve of scientific progress follows; indeed I might say that the forward movement is of an explosive type, where the rebound is an attendant characteristic of the advance. Every applied hypothesis which succeeds in throwing the searchlight of a new vision across the field of physical science represents a plunge into the darkness; because we cannot at first reduce the vision to a logical statement. Then follows the birth-struggle of a new theory. Once this has seen the light of day it has to go forward willy-nilly until the stamp of its destiny is put on it when the test of the research measurements is applied."*

Max Planck

- No result in science is a terminal point. Each result is a synapse, a nodal point in an intricate tapestry, forever unfinished, different parts being woven by different master weavers working towards a common yet hidden pattern more and more pleasing to our senses and sensibilities as the weaving progresses; the master weavers with partial agreement concerning the tools to be employed, the scientific method.

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- Induction refers to arguments concerning premises about some members of a class leading to conclusions about certain other members of the class or the whole class.
- Unlike deduction which consists in demonstrative reasoning, as from axioms to theorems in mathematics, induction involves non-demonstrative reasoning. A demonstrative argument from a true premise necessarily leads to a true conclusion. However, a non-demonstrative argument from a true premise does not necessarily lead to a time conclusion.

- What constitutes the evidence that forms the basis for induction? How is this evidence garnered? Is experience the basis for evidence? Is this experience the experience of a particular individual or the experience of a collection of individuals? Is such evidence purely emperical in nature and if it is so what is the certainty associated with such evidence? Should the evidence be purely based on sense-experience? Can one trust sense-experience? We need to answer all the above questions and many more before we can start assessing the validity of induction.

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- As we are concerned with the development of scientific theories, we would be justified in accepting as experience, public experience. Private experience has no place in science unless it is also borne out by public experience. We will also have to allow as evidence not only direct observations, but also indirect observation as through a microscope, or that from a thermometer.

- Induction is usually regarded as going from the particular to the general. However, Carnap asserts that such a definition could be misleading and simplistic as there are various means of drawing inferences that are used in induction. He prefers to assign the terminology inductive logic to that procedure that helps determine the probability of a conclusion being correct, given a set of correct premises.

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- *"The empirical basis of objective science has nothing absolute about it. Science does not rest on a solid bedrock. The bold structure of its theories rise, as it were, above a swamp. It is like a building erected on piles. The piless are driven down from above into the swamp, but not down to any natural or "given" base; and when we cease our attempts to drive our piles into a deep layer, it is not because we have reached firm ground. We simply stop when we are satisfied that they are firm enough to carry the structure, at least for the time being.*"

Popper

- Science is about asking the right question, not about finding the right answer. In fact, one can think of reasoning as a function whose domain is Science (the set of all right questions) and whose co-domain the set of approximate explanations. All models are approximations.

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- Pure mathematics versus Applied mathematics seems to go back to times immemorial:

- *"These machines he [Archimedes] had designed and contrived, not as matters of any importance, but as mere amusements in geometry; in compliance with King Hero's desire and request, some little time before, that he should reduce to practice some part of his admirable speculation in science, and by accommodating the theoretic truth to sensation and ordinary use, bring it more within the appreciation of the people in general. Eudoxus and Archytas had been the first originators of this far-famed and highly-prized art of mechanics, which they employed as an elegant illustration of geometrical truths and as means of sustaining experimentally, to the satisfaction of the senses, conclusions too intricate for proof by words and diagrams.*

- *"As, for example, to solve the problem, so often required in constructing geometrical figures, given the two extremes, to find the two mean lines of a proportion, both these mathematicians had recourse to the aid of instruments, adapting to their purpose certain curves and sections of line, But what with Plato's indignation at it, and his invectives against it as mere corruption and annihilation of the one good in geometry, which was thus shamefully turning its back upon the unembodied objects of pure intelligence to recur to sensation, and to ask help (not to be obtained without base supervisions and depravation) from matter; so it was that mechanics came to be separated from geometry, and, repudiated and neglected by philosophers, took its place as a military art."*

Engineer [ME. engyneour, OF. engigneor, L. ingeniatorem]

1 One who contrives, designs or invents; an author, designer of, inventor, a plotter, a layer of snares.
1420 – In hys court was a false traytoure. That was a great Yngynore.
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4. A contriver or maker of engines.

Engineering $\sim$ Applied Physics
$\sim$ Applied Natural Philosophy

Division of Engineering into: Mechanical Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Aerospace Engineering, Biomedical Engineering, Petroleum Engineering, Materials Engineering, Bio Engineering . . . Is Arbitrary.

There is substantial overlap amongst the areas.

Similarly the division of Mechanical Engineering into: Thermodynamics, Combustion, Fluid Mechanics, Solid Mechanics, Design Manufacturing, Metrology, Robotics, Machine elements, Controls, Dynamical Systems & Vibrations, —— IS EQUALLY ARBITRARY.

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- Psychological, Biological, Ethics, Morals, Philosophical and other considerations.

Each aspect referred to above requires a variety of tools from mathematics. However, we should bear in mind all that mathematics can do is to provide an approximate description:

"As far as the laws of mathematics relate to reality, they are not certain, and as far as they are certain, they do not refer to reality."

– Einstein

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   Turbulent: Partial Differential Equations (Stochastic)
   Direct Numerical Simulations
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- AND SO ON.

Let us look at it from another perspective:

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8. Abstract Geometry: Design

Example I

APPLICATION OF GROUP THEORY:

$\mathcal{B}$ – Abstract Body – Set of Particles

$\mathcal{B}$ – Measure (mass), Topology (subbodies)

Motion: $\mathbf{x} := \chi(\mathbf{X}, t)$

Deformation Gradient: $\mathbf{F} := \dfrac{\partial \chi}{\partial \mathbf{X}}$

Elastic Material: $\mathbf{T} = \mathbf{f}(\mathbf{F}, \mathbf{X})$

Homogeneous Elastic Body: $\mathbf{T} = \mathbf{f}(\mathbf{F})$

Material Symmetry: Mechanical, Optical, Thermal, Electrical, etc.

Mechanical Material Symmetry:

$\mathcal{G}_\kappa := \{\mathbf{H} \in \mathcal{U} | \mathbf{f}_\kappa(\mathbf{FH}) = \mathbf{f}_\kappa(\mathbf{F})\},$

$\mathcal{U} =$ Unimodular Group.

$\mathcal{O} =$ Orthogonal Group.

If $\mathcal{G}_\kappa = \mathcal{U}$, the body is said to be ISOTROPIC.

$\mathcal{U}, \mathcal{O}$ – Lie Groups.

$\mathcal{O}$ is the maximal subgroup of the unimodular group $\mathcal{U}$.

$\rightarrow$ There are no symmetries that are greater than in an isotropic solid, unless we have a fluid.

$\mathcal{G}_\kappa$ is a group.

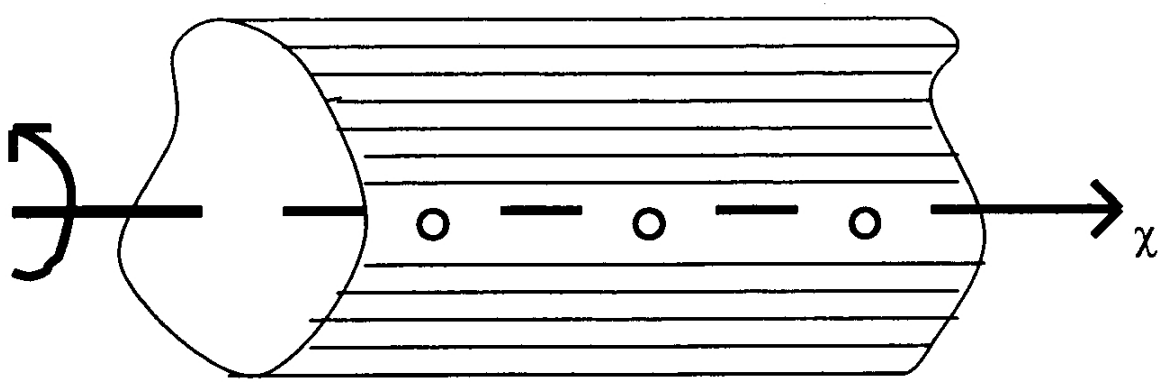
Depending on the group, we have representation theorems that tell the form of $\mathbf{f}(\mathbf{F})$.

For instance, if $\mathcal{G}_\kappa = \mathcal{O}$ then

$$\mathbf{T} = \mathbf{f}(\mathbf{F}) = \mathbf{g}(\mathbf{B}) = h_1\mathbf{I} + h_2\mathbf{B} + h_3\mathbf{B}^2,$$

where $\mathbf{B} := \mathbf{F}\mathbf{F}^T$, $h_i = h_i(I_\mathbf{B}, II_\mathbf{B}, III_\mathbf{B}), i = 1, 2, 3$

$I_\mathbf{B} = \mathrm{tr}\mathbf{B}, II_\mathbf{B} = \frac{1}{2}[(\mathrm{tr}\mathbf{B})^2 - \mathrm{tr}\mathbf{B}^2], III_\mathbf{B} = \det\mathbf{B}.$



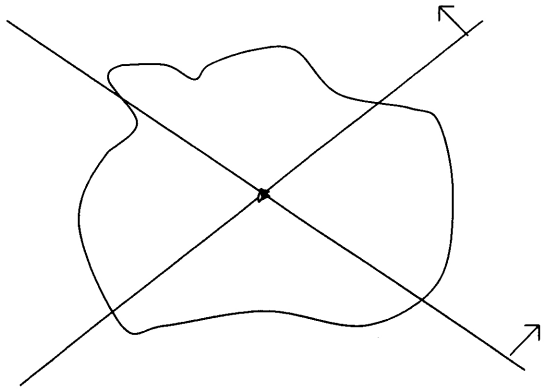
Fibers parallel to the χ-axis.

The stress response will be the same provided the cylinder is rotated about the χ-axis.

In this case $\mathcal{G}_\kappa = \mathcal{T}_r$ where $\mathcal{T}_r$ is called the Rotational Transverse Isotropy group.

Once again group theory and representation on groups provide the representations for the stress.

Orthotropy



Two mutually orthogonal planes across which reflections leave the bodies response invariant.

SHOULD NOT CONFUSE SYMMETRY OF SHAPE (GEOMETRY) WITH SYMMETRY OF RESPONSE.

Instead of stress, let us define the Helmholtz potential for an elastic solid from which the stress can be derived.

$$\psi = \psi(\mathbf{F}) \text{ Helmholtz Potential}$$
$$= \psi(\mathbf{B}) \text{ Frame Indifference}$$

If $\mathcal{G}_\kappa$ = Orthotropy Group, and **m** and **n** are the unit normals to the two planes, then

$$\psi = \psi(\mathrm{I}_1, \mathrm{I}_2, \mathrm{J}_1, \mathrm{J}_2, \mathrm{K}_1, \mathrm{K}_2)$$

$\mathrm{I}_1 = \mathrm{tr}\mathbf{B}, \mathrm{I}_2 = \mathrm{tr}\mathbf{B}^2, \mathrm{J}_1 = \mathbf{n}.\mathbf{C}\mathbf{n}, \mathrm{J}_2 = \mathbf{n}.\mathbf{C}^2\mathbf{n}, \mathrm{K}_1 = \mathbf{m}.\mathbf{C}\mathbf{m}, \mathrm{K}_2 = \mathbf{m}.\mathbf{C}^2\mathbf{m}$, where $\mathbf{C} := \mathbf{F}^T\mathbf{F}$.

SYMMETRIES INDUCED DUE TO DEFORMATION

When a body is deformed due to the deformation symmetries change.

In many engineering applications we desire a particular symmetry.

Film Blowing
Metal Working (We require a certain TEXTURE)

Inverse Problem:

How do you process the material to achieve desirable symmetries?

What is the representation for the stress?

What can we say about the governing equations?

Aside
Inelasticity (Metal Working) leads to interesting problems in Non-Euclidean Geometry.

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Some Final Remarks About Modeling in Continuum Mechanics

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- The basis for the study of Mechanics ought to be “chunks” rather than “points” and “intervals” rather than “instants”.
- It should be possible to introduce the notion of the smallest “chunk”. This would be a “Representative Volume", for instance in a crystalline solid, the smallest geometric structure that is repeated. One needs to think through what is relevant for amorphous materials and fluids (it might be related to the notion of the mean free path in different directions).

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- Ideas such as “anisotropy” refer to the response with regard to the orientation of such smallest possible “chunks” (one could allow for “chunks” that are reflections of a “chunk” as an admissible “chunk”).

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- Homogenization that leads to field equations are merely assignments of the properties of the “chunks” to “points” that are within the “chunk”.

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- Even if we continue to operate within the confines of the current use of points, lines, etc., we need to think of balance laws (governing equations) and their solutions within the context of appropriate integral representations.
- In this sense we have to think of properties of a body that assigns to sets a value, which might itself be a set.

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- Descriptions of a body should be about the "here and now" with extensions to the past, i.e., we should use relative deformation gradients even to describe elastic bodies.
- One should go away from the class of simple materials, they are grossly inadequate to describe complex material response that one observes.

Thank You